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LOCKHEED-GEORGIA COMPANY

A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

MARIETTA GEORGIA

TITLE

PROPOSAL FOR TEST PROGRAM TO EVALUATE
ELECTRICAL BONDING OF ASSEMBLIES
UTILIZING ENVIRONMENTAL SEALING

SUBMITTED UNDER
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6-15-64	BEH	ii, iii, iv, ... 5, 6, 7, 10, 11, 12, 13, 14, ... 17, ... 21, 22, ...	This revision reduces the types of fasteners and combinations of sealants used in these specimens.
11-11-64	BEH	5	Clarification of purpose per USAF request.
6-1-65	BEH	..., 17, 19, 20, 21, 22, 23	Change in filler dimensions and test method

FOREWORD

The Lockheed-Georgia Company submits this unsolicited proposal to the U. S. Air Force C-141 Systems Project Office in answer to a need to evaluate the electrical bonding existing when recent advances in environmental sealing are incorporated during airframe construction.

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SUMMARY

The art of corrosion prevention of an airframe is advancing through the increasing use of faying surface sealing, "wet" installation of fasteners, and related corrosion prevention techniques. It is suspected in a recent civil jet aircraft accident where an outboard tank exploded that a lightning strike to the wing tip was the source of ignition. This situation has caused the Lockheed-Georgia Company to review electrical bonding of aircraft structure in relation to corrosion inhibiting techniques. This review shows that environmental sealing now used and contemplated for the immediate future may result in a lack of metal-to-metal contact of structure, and that this could produce a safety hazard in integral fuel tank areas. In view of the safety aspects of the situation, Lockheed believes it is essential to positively determine the electrical bonding existing when these new environmental sealing techniques are used.

This proposal defines a test and evaluation program intended to determine the electrical conductivity of structure, down to the individual fastener, when various combinations of environmental sealing are used.

A total of 32 specimens are built. They are divided into two identical sets of butt joints of 13 per set, two control specimens for instrumentation check and calibration, and four wing joint specimens of two configurations as shown on Figures A4 and A5. One set of butt joints is investigated for conductivity before and after environmental aging. The second set of butt joints is investigated by Lightning and Transients Research Institute before and after environmental aging. The four wing joint specimens are also investigated by LTRI before and after environmental aging.

I - INTRODUCTION

Good electrical bonding of the airframe has long been an airplane design requirement. This is to ensure lightning protection, electrical current return paths, the prevention of interaction between electronic equipment, homogeneous ground planes and paths for antennas, the control of precipitation static and radio frequency interference, and the elimination of electrical potential differences between structures which might generate arcing to create explosion hazards or shock hazards to personnel. Standard aircraft construction practices developed over the years have proved satisfactory in the past, but the following factors require a re-evaluation of electrical bonding. A recent civil aircraft accident where lightning was the suspected cause has initiated intensive studies by both government and industry of lightning hazards, with particular attention to fuel systems. New anti-corrosion techniques, using a sealing compound between all metal-to-metal surfaces and installation of fasteners "wet", appear counter to good electrical bonding techniques.

Recently the U. S. Air Force has asked Lockheed for ECP action to extensively increase the environmental sealing of C-141A aircraft on exterior airframe joints. Because of the conjunction of this Air Force proposal and the suspected destruction of a jet aircraft by lightning, Lockheed believes that a careful study must be conducted of electrical bonding with and without the proposed environmental sealing techniques. This report proposes a program that will:

(1) Determine the effects of environmental sealing on electrical current flow and electrical bonding of the test specimens.

(2) Determine the effect on current flow and note any differences between specimens when simulated lightning strikes are discharged through the test specimens.

(3) Compare the observed test results in order to determine if the proposed corrosion protection is detrimental to electrical bonding. (Final determination of the magnitude of the detrimental effects, if any, and their effect on the C-141 Program shall be accomplished through joint LGC-SPO action.)

II - TECHNICAL APPROACH

The way chosen to evaluate the electrical bonding characteristics of C-141A airframe construction is by electrical measurements made on standardized evaluation specimens. Current is passed through the specimen and the current flow is determined by measurement of the voltage drop along the surface of the specimen. This technique discloses the current distribution around the individual fasteners as well as throughout the rest of the aluminum sheet. Appendix A specifies the samples that are constructed using a variety of faying surface finishes, fasteners, and fastener installation techniques. Table A-I calls for two sets of specimens of 13 each, totalling 26. One of these sets is used for conductivity tests while the other is being investigated from a lightning standpoint.

In addition, two reference specimens are built in accordance with Figures A-2 and A-3 to serve as controls. One is a continuous length of aluminum. The other is built with a simple insulated butt joint and conducting fasteners. These specimens serve to check the measuring equipment and as a standard of comparison for the evaluation specimens.

The current distribution measuring technique is described in Appendix B. A dc current is passed through the sample and the voltage drop is measured at the surface of the aluminum with a microvoltmeter. Lines of constant potential are drawn on the sample and the current distribution is deduced from the fact that current flows perpendicular to constant potential lines.

The specimens are first measured in the newly fabricated condition to determine their initial status. The specimens are then environmentally aged for 30 days as specified in Appendix A and again measured. This shows the deterioration in electrical conductivity after this severely accelerated aging process.

As far as is known, measurements of the type described in Appendix B have not been done before. There are no known impedements to this method, however, it is pointed out that changes in technique could be required during the course of the work.

III - LIGHTNING EVALUATION

The purpose of striking evaluation specimens with laboratory-produced simulated lightning is to determine the effects of the high-magnitude transient current on these assemblies that are similar to the construction used in the C-141A aircraft.

The possibility of sparking inside the wing fuel tanks as a result of a lightning strike is of particular concern at the present time.

Two configurations are called for that are particularly intended to disclose any possible fuel ignition hazards. Figure A-4 shows the construction of one that closely simulates the C-141 midwing panel splice. The wing panels are continuous from wing tip to this splice and then to the fuselage attachment. The second is shown in Figure A-5 and shows the construction of the wing tip bulkhead to panel joint. Both of these joints are wetted by fuel on one side. It is essential that they provide a low resistance non-sparking path for currents resulting from a wing tip strike. Two specimens of the Figure A-4 and A-5 configurations are constructed with finishes and sealant identical to the actual C-141 airplane. Two more specimens are made using an experimental conductive sealant that may have advantages over the presently used sealant. These four specimens are investigated for lightning conductivity characteristics in the "new" condition. They are then environmentallly aged as specified in Appendix A, and again evaluated.

One set of butt joint specimens built in accordance with Figure A1 and Table A-I is investigated for lightning conductivity under lightning simulated conditions in the "new" condition. They are aged in accordance with the procedures in Appendix A and again evaluated.

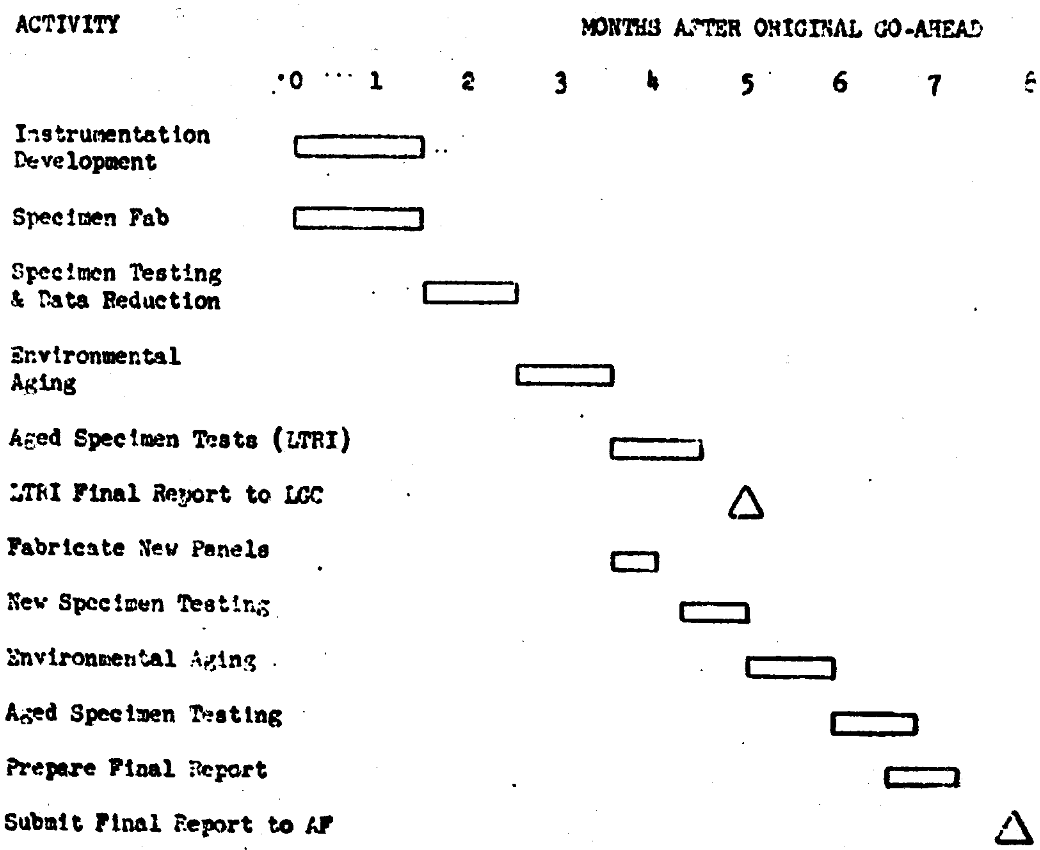
The lightning investigations are conducted by Lightning and Transients Research Institute. Data is collected by photographic and oscillographic techniques to detect any sparking at the joints that may take place during the simulated lightning strike.

LTRI is uniquely qualified to conduct the investigative work called for in this proposal. They have the technical competence, experience, and laboratory facilities to expeditiously complete the work. The Lockheed-Georgia Company has maintained a close working relationship with LTRI over the past several years on C-130, C-140, and C-141 project activities as well as participation in the LTRI Industry Cooperative Program.

IV - PROGRAM SCHEDULE

The revised program covers a period of slightly over seven months as noted below. Monthly progress letters are issued during the program with a test report issued upon completion of testing.

TABLE 1 - PROGRAM SCHEDULE



APPENDIX A

PREPARATION OF SPECIMENS

PREPARATION OF SPECIMENS

I. Specimens simulating typical aircraft joints are constructed as shown in Figure A-1. The chemical finish, organic finish, and type fasteners are shown in Table A-I.

TABLE A-I - BONDING TEST SPECIMENS

FAY SURFACE AND FASTENER TREATMENT (NOTE 1) / FASTENER TYPE	RIVETS (NOTE 2)	LOCKBOLTS (NOTE 3)	HI-LOCKS (NOTE 4)
FASTENERS INSTALLED DRY - NO FAY SURFACE SEALANT	2 EACH	2 EACH	2 EACH
FASTENERS INSTALLED WET WITH MIL-S-8802 - NO FAY SURFACE SEALANT	2 EACH	2 EACH	2 EACH
FASTENERS INSTALLED WET WITH MIL-P-8585 - FAY SURFACE SEAL WITH MIL-S-8802	2 EACH	2 EACH	2 EACH
FASTENERS INSTALLED WET WITH MIL-S-8802 - FAY SURFACE SEAL WITH MIL-S-8802	2 EACH	2 EACH	2 EACH
FASTENERS INSTALLED WET WITH MIL-S-8802 - FAY SURFACE SEAL WITH CONDUCTIVE SEALANT	2 EACH	-	-

NOTE 1: Clad 7079 - MIL-C-5541 clear conversion coating for all samples. Bare 7075 splice plates - MIL-C-5541 colored conversion coating for all samples. Outer skin is to remain unpainted. Inner skin is coated with one coat of MIL-P-8585 zinc chromate primer. Splice plate is coated (overall) with two coats of zinc chromate. The first coat is cured before applying the second.

(TABLE A-I continued)

NOTE 2: MS 20426-AD5 Rivets - Install per LAC 0581.

NOTE 3: SAL 100T6-2 Lockbolts and 6LC-C6 Collar - Install per LAC 0581 and DS 5041.

NOTE 4: HL 51-6-3 Hi-Lock and HL 90-6A Collar - Install per LAC 0581 and DS 5055.

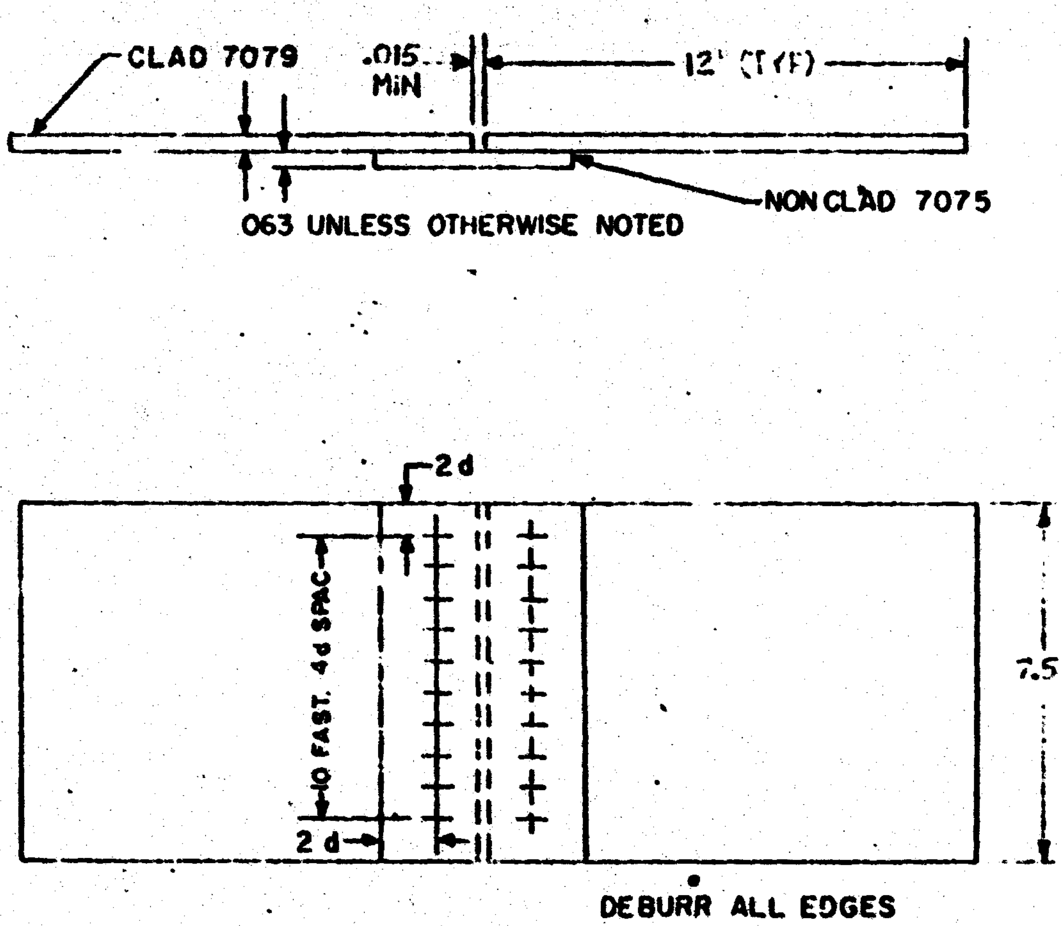


FIGURE A1 - BUTT JOINT SPECIMEN

In addition to the above test specimens, two specimens are constructed as shown in Figures A-2 and A-3 for control and reference purposes.

After conducting the electrical tests called for in Appendix B, the samples of Table A-I are environmentally aged and re-tested.

For the purpose of environmental aging, the following cycle is used for a period of 30 days:

CYCLE -

1. Immerse in alkaline cleaner 1 minute - set for 1 hour.
2. Rinse in water - dry 150°F for 1 hour.
3. Immerse in stripper 1 minute - set for 1 hour.
4. Rinse in water - dry 150°F for 1 hour.
5. Immerse in brightener for 1 minute - set for 15 minutes.
6. Rinse in water - dry 150°F for 1 hour.
7. Weather-o-meter

Alkaline Cleaner, MIL-C-25769
10-1 dilution with water

Paint Stripper, MIL-R-25134
concentrated

Brightener, Cee Bee Chemical Company (B-55)
concentrated

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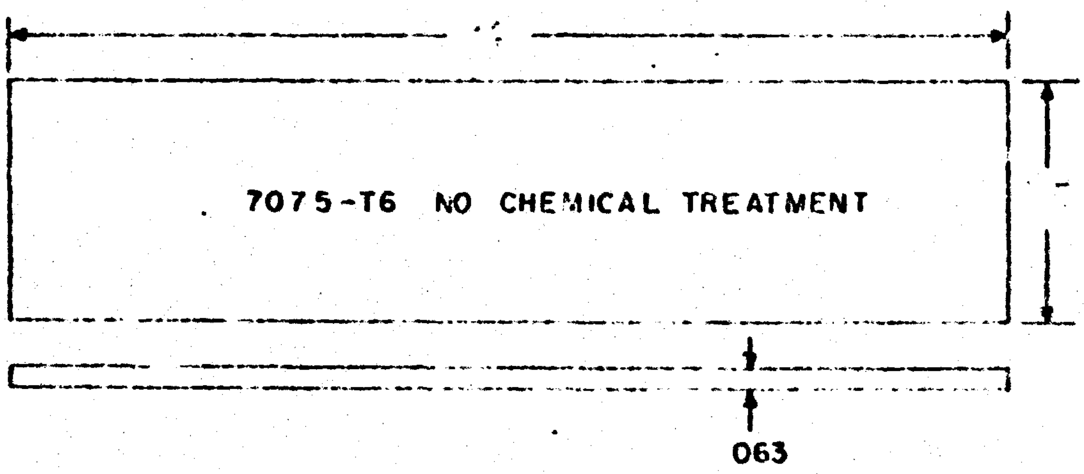

FIGURE A2-CONTINUOUS ALUMINUM REFERENCE SPECIMEN

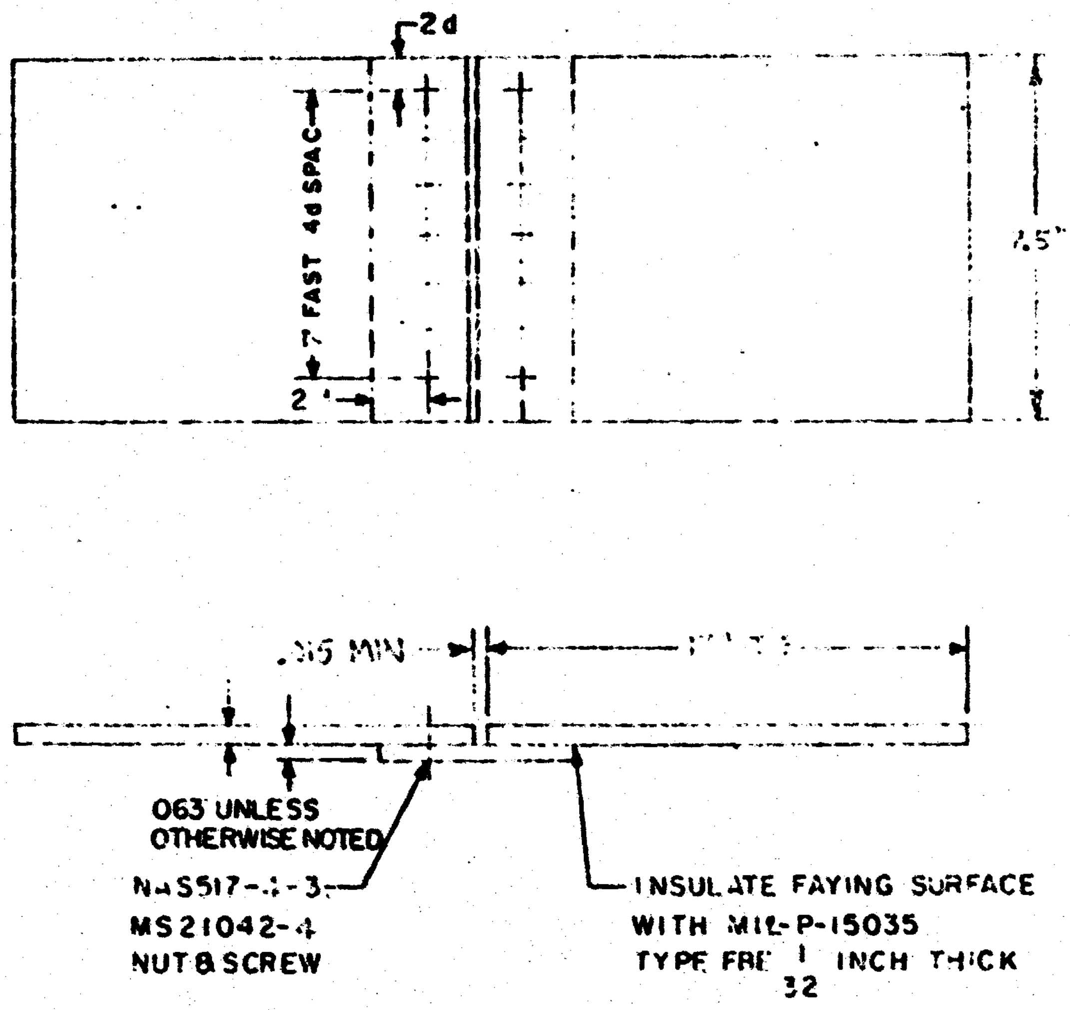

FIGURE A3 - BUTT JOINT REFERENCE SPECIMEN

II. Wing Specimens for Lightning Strike

Four specimens are prepared primarily for lightning strike investigation. These four specimens are in two configurations as follows:

1. The first specimen represents the C-141 manufactured joint on the surface of the wing box beam structure at CWS 405 as shown by Figure A4. Surface treatment and fay surface sealant are identical to the aircraft.

2. The second specimen is identical to the first except that the fay surface sealant is a conductive sealant.

3. The third specimen represents the joint at the outer wing tip of the upper surface wing panels to the end bulkhead as shown by Figure A5. Surface treatment and fay surface sealant are identical to the aircraft.

4. The fourth specimen is identical to the third except that the fay surface sealant is a conductive sealant.

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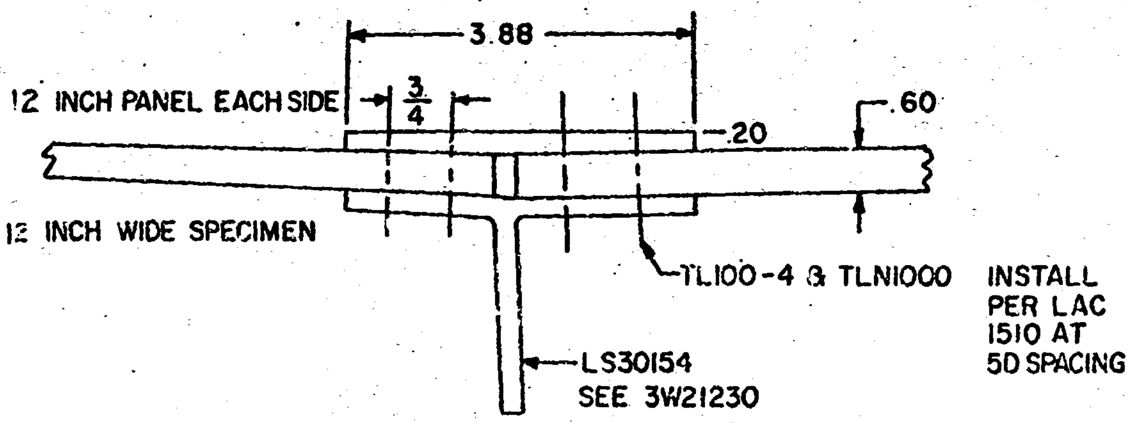

FIRST SPECIMEN:
ALL PARTS 7075-T6
SULFURIC ACID ANODIZE ALL PARTS PER MIL-A-8625
APPLY ONE COAT MIL-C-27725 PER 6-639
FAY SEAL WITH MIL-S-8802, CLASS B SEALANT

SECOND SPECIMEN:
SAME MATERIAL AND TREATMENT AS ABOVE, EXCEPT THE FAY SEALANT IS A CONDUCTIVE SEALANT

FIGURE A4 - MID-WINGPANEL SPLICE

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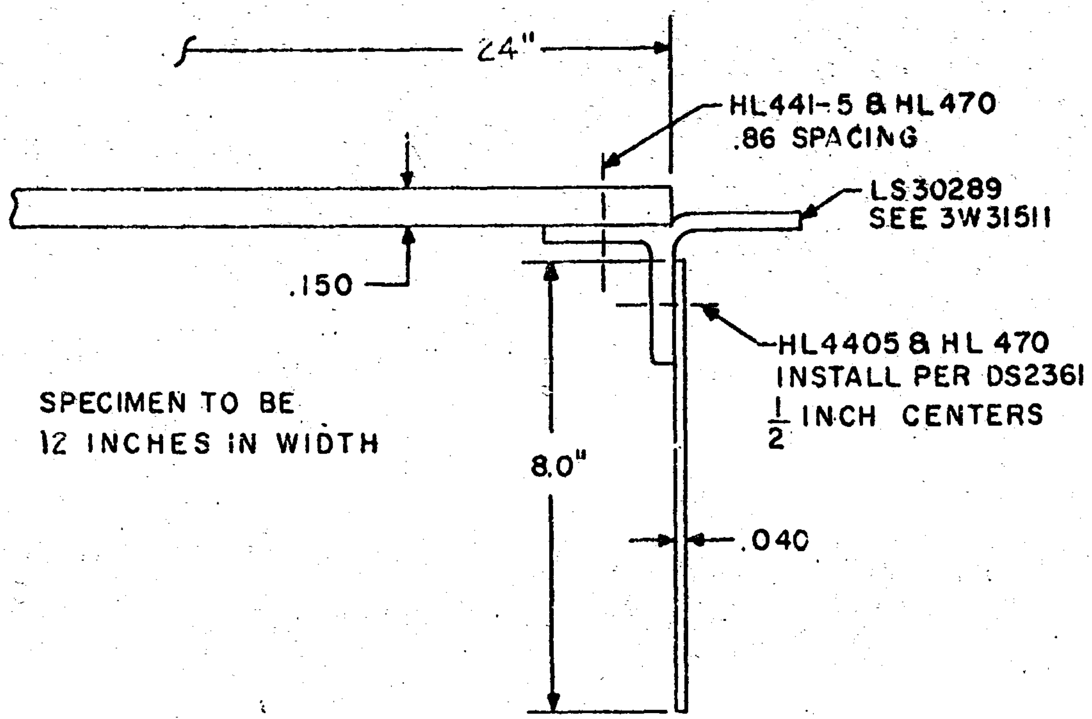

SPECIMEN TO BE
12 INCHES IN WIDTH

FIRST SPECIMEN:

ALL PARTS 7075-T6
SULFURIC ACID ANODIZE ALL PARTS PER MIL-A-8625
APPLY ONE COAT MIL-C-27725 PER G-639
FAY SEAL WITH MIL-S-8802, CLASS B SEALANT
INSTALL FASTENERS WET WITH MIL-S-8802 SEALANT

SECOND SPECIMEN:

SAME MATERIAL AND TREATMENT AS ABOVE, EXCEPT THE FAY SEALANT IS A CONDUCTIVE SEALANT.

FIGURE A5 - WING TIP BULKHEAD TO PANEL JOINT

APPENDIX B

TEST PROCEDURES

TEST PROCEDURES

I. General

The ultimate objective of the test program is to determine the electrical current distribution, and hence bonding effectiveness through sample structural specimens which are representative of all types of joints and fasteners in use in C-141 aircraft construction.

Before the start of actual testing the two reference specimens are examined to define reference current distributions in samples having no joints, and joined samples.

II. Test Equipment

Concept - Current flowing in a conducting material of known physical dismensions and known resistivity may be determined by measuring the voltage drop across the material. The method used in this investigation employs a d-c power source connected across the test specimen in series with an adjustable load bank. The current through the specimen is adjusted to 50 amperes and the voltages between one end of the specimen and other points on its surface are measured with a sensitive microvoltmeter. Lines are then drawn through points of constant potential. Since current always flows at a right angle to a constant potential line, these lines form a gradient map of the current flow pattern in the specimen.

Test Setup - The test setup is shown in Figure B-2. The specimen to be tested is fastened securely to a nonconducting base and the current through it is adjusted to 50 amperes by adjusting the resistance of the

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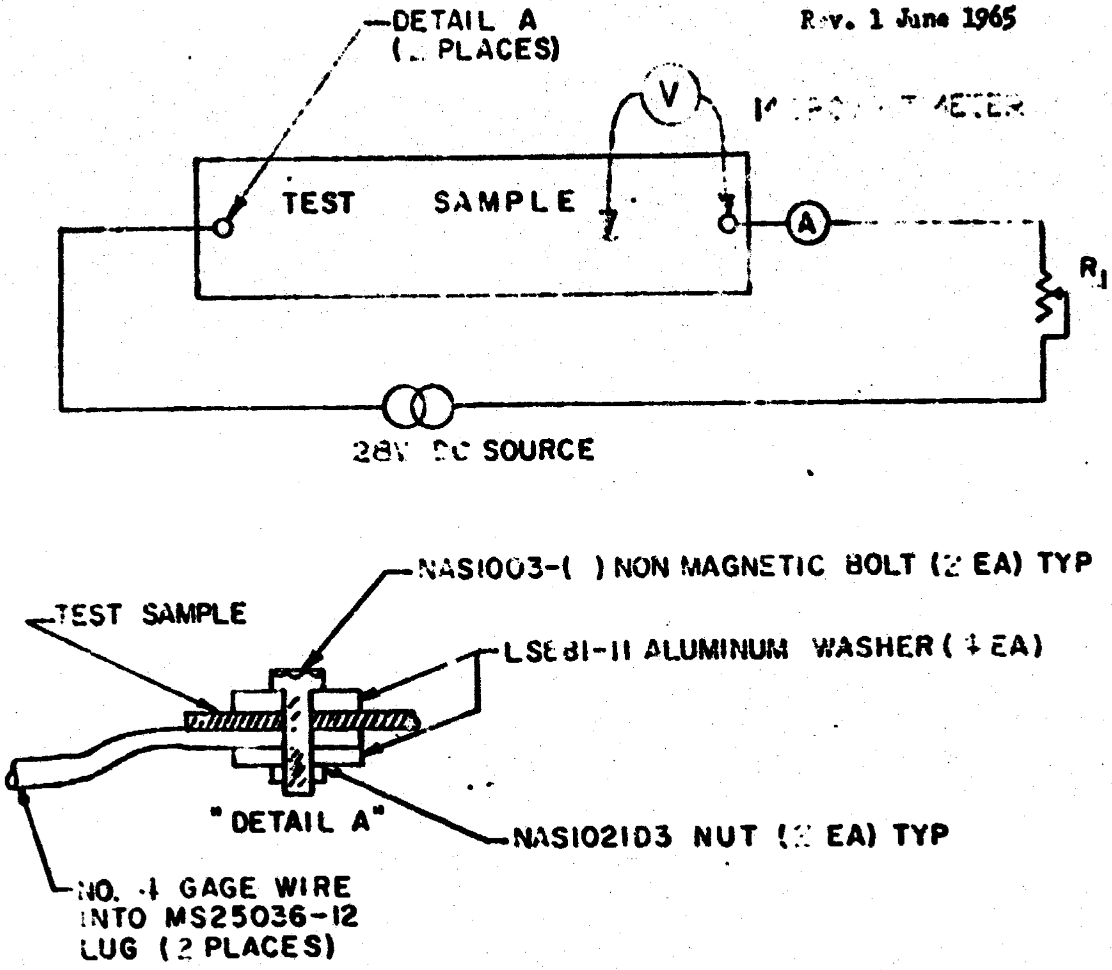

NOTE:

1. TEST SAMPLE CLEANED EACH SIDE BEFORE INSTALLATION OF BOLT
2. BOLTS TO BE TORQUED TO 30 IN LBS.

FIGURE B1-ELECTRICAL DIAGRAM OF TEST SET-UP

<u>Test Setup Continued</u> - load bank. The ground lead of the microvoltmeter is attached to the end of the panel where the d-c power lead is connected and the probe is used to measure the voltage between that point and any other point on the surface of the specimen.

Points on the surface of the specimen having the same potential will be marked and a line drawn through them representing a constant potential line. These constant potential lines will be drawn at regular intervals along the surface of the specimen. In the area of the joint, additional constant potential lines will be drawn in order to provide as complete a map of the current distribution as possible. The meter ground lead will be removed from the end of the specimen and placed on a constant potential line in the area of the joint for making these additional lines. This allows the sensitivity of the microvoltmeter to be increased in order to improve the resolution of the lines in this area.

In addition, the potential of each of the fasteners will be measured and recorded along with that of the back plate of the joint. The resistance of the entire specimen will also be determined by measuring the potential drop from one end of the specimen to the other.

<u>Reference Specimens</u> - In order to define effects of various test setup parameters not directly associated with the test specimens it is necessary at program commencement to run several tests on two reference specimens. The first reference specimen is a continuous sheet of structural

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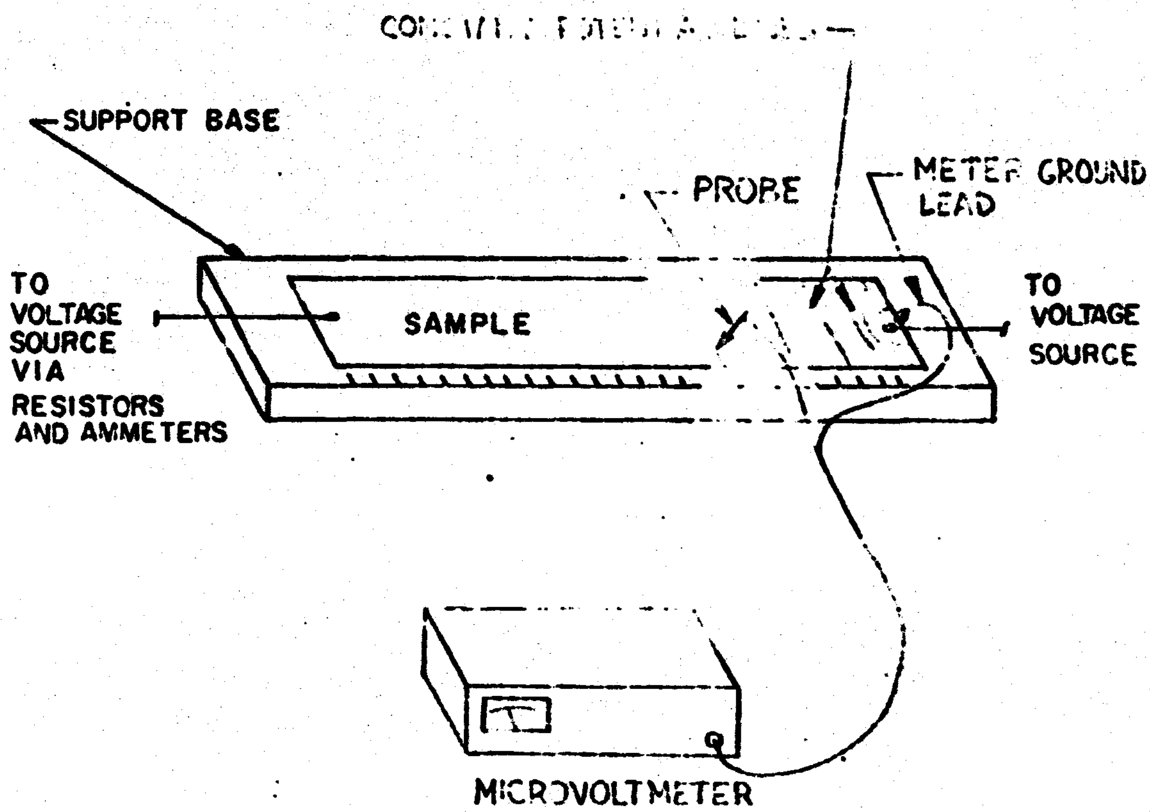

FIGURE B2 - PHYSICAL TEST SET-UP

aluminum having no joints. Tests on this panel show normal current distributions and permit evaluation of the effects of power electrode attachments on the distribution. The second reference specimen has a butt joint which is electrically insulated so that the fasteners along will conduct across the joint. Tests are made to determine current distribution through these fasteners. Certain fasteners are then removed sequentially to simulate installation of electrically insulated fasteners so that their effects on the current through the remaining fasteners are determined. This procedure permits the test operators to look for these conditions during actual tests. Other specimens may be made as required to simulate any unusual results.